(NASA-TM-83845) AE-5 END OF MISSION TESTS REPORT (NASA) 37 p HC A03/MF A01 CSCL 22B

N82-12099

Unclas
G3/15 03295

NASA

Technical Memorandum 83845

AE-5 End of Mission Tests REPORT

T. H. Stengle
F. Kissel
J. Schaefer
F. Kalil

OCTOBER 1981

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

AE-5 END OF MISSION TESTS

REPORT

October 1981

Thomas H. Stengle
F. Kissel
J. Schaefer
F. Kalil

Preface

The End-of-Mission (EOM) Tests on Atmospheric Explorer-5 (AE-5) were performed in response to a request from NASA Headquarters. Pursuant to the request, test proposals were solicited from the technical community (GSFC engineers, NASA centers, universities, and industry). For the selected/approved tests, the proposers (test engineers) prepared detailed test Plans with procedures which were carried out by the Orbiting Satellites Project/Science with support from the project's contractors (RCA and Westinghouse), and under the direction of the EOM Test Manager, Dr. Ford Kalil. The test engineers were responsible for analyzing their data and preparing their reports. This test is a consolidation of those reports into this final report, "AE-5 End-of-Mission Tests Report."

Summary

Of the eleven EOM tests that had been proposed and accepted, only two could be performed because of conflicts with science or problems with scheduling. The tests conducted were the spin up test and the simulation of "tracking" a Tracking and Data Relay Satellite (TDRS).

In the spin up test, the AE-5 was spun up to 10 rpm from its nominal 4 rpm to determine if it would be feasible to use the Body Horizon Scanner (BHS) on other spacecraft having spin rates up to 10 rpm. It was found to be feasible. The BCH data at the higher spin rate was successfully used to determine the AE-5 spacecraft attitude.

The TDRS simulation test showed that an AE-5 type attitude control system (ACS) could be successfully used to point the spacecraft towards a TDRS for the purpose of transmitting data via the TDRS.

Table of Contents

I. INTRODUCTION

NASA's Chief Engineer requested that each project develop a terminal test program for acquiring engineering information prior to shutdown or reentry of an operational satellite (Ref. 1). NASA's Director, Astrophysics Division, concluded that engineering tests for end-of-mission satellites could be useful, if properly planned and executed, and the data disseminated to those who will use the results for future spacecraft development. Primarily, contractors, their subcontractors, and in-house engineers involved in the original spacecraft development and who will be involved in future projects would derive the most benefit from the end-of-mission tests (Ref. 2). As a preliminary step in responding to the requirement (Ref. 1), GSFC was requested to prepare engineering test plans for AE-5. The test plans were submitted to by NASA Headquarters for approval.

Table I-1 summarizes the approved plan, test sequence and test synopses. Only two of the eleven tests were performed because of the priority of collecting scientific data over performing engineering tests. As seen from Table I-1 many of the tests were not permissible except during the last one or two orbits. The two tests that were performed were tests 1 and 2 in Table I-1.

The purpose of this report is to present the tests that were conducted, their results and conclusions, so that contractors, subcontractors, and in-house engineers who are involved in spacecraft development could derive benefit from the tests.

---

1. Letter from Walter C. Williams, Code D, NASA Hq. to associate Administrators of Codes E, M, R, S, and T, NASA Hq., Subject: Engineering Uses of Satellites at End of Mission, 17 Nov. 1978.
2. Letter from T.B. Norris, Code SC-7, NASA Hq. to Director, GSFC, Subject: Same as Ref. 1, March 28, 1979.

TABLE I-1

AE-5 END-OF-MISSION TESTS

TEST NO.	TEST ENGR. & ORG.	TEST NAME	TEST DESCRIPTIONS & COMMENTS	SCHEDULE
1	D. Skillman GSFC/734.2	TDRSS Tracking Sim.	Track the moon with VAE Photometer; This would test the ACS. Info useful for DE-8. 1 man-month. 2 weeks to prepare & perform test.	Routine*
2	G. Meyers, T. Stengle GSFC/581.2	Spin-up Test	Spin-up AE-5 to 10 RPM. Evaluate body horizon scanner useful for DE-A pre and post separation spin rates.	Routine*
3	P. Brandt, D. Rhodes RCA	Magnetic Torquer Test	Pulse the magnetic torquers to determine effects upon the on-board computer memory.	Routine*
4	K. Champion, P.I. U.S.A.F. GEOPHY LAB., MASS.	Minature-Electrostatic Accelerometer (MESA) Accelerometer Test	Routinely and periodically exercise all constrainment and suspension commands on MESA accelerometer.	Routine*
5	"	Reentry data with MESA	Use MESA to monitor vehicle dynamic accelerations at End-of-Mission maneuvers of other tests and during "reentry."	Routine* & During "Reentry"
6	J. Cooley GSFC/581.3	Propulsion System	Fire the thruster cross coupling explosive valve. Test contingency plan and for gaining use of trapped fuel.	Last 1 or 2 orbits

TABLE I-1 (continued)

AE-5 END-OF-MISSION TESTS

TEST NO.	TEST ENGR. & ORG.	TEST NAME	TEST DESCRIPTIONS & COMMENTS	SCHEDULE
7	D. Suddeth GSFC/734.2 C. Chapman Westinghouse	Contamination due to propellant exhausts	When fire trapped fuel from J. Cooley's test, detect or measure contamination due due to propellant exhausts via the optical instrumentation onboard AE-5.	In conjunction with test 6
8	B. Kennedy P.I., Univ. of Michigan	Visual Airglow Expt	Exercise all cmd states to determine if any unused functions have failed.	Routine*
9	F. Kalil GSFC/730.2 C. Chapman Westinghouse	Uncage Dampers	Uncage both dampers & evaluate S/C performance	Last 1 or 2 orbits
10	F. Kalil GSFC/730.2 C. Chapman Westinghouse	In-orbit Redundancy Checks	Check all redundant units in-orbit; only redundant tape recorder and memories have been checked in-orbit. Also, check the "non-preferred" wheel horizon scanner.	Last 1 or 2 orbits
11	G. Halpert GSFC/711.4 M. Tasevoli GSFC/711.4	Battery Performance	Measure battery performance at End-of-Life	Last 1 or 2 orbits

* Routine tests can be performed anytime on a non-interfering basis with science.

SECTION II

AE-5 SPIN UP END OF MISSION TEST

Thomas H. Stengle
Fred J. Kissel

Summary

The AE-5 Spin Up test was conducted 21 November 1980. Analysis of telemetry data from the Body Horizon Sensor (BHS) showed satisfactory operation at a spin rate of 10 rpm, thus simulating the operation of the BHS when used with the DE spacecraft. The data was successfully used to compute the attitude of the spacecraft.

1.0 INTRODUCTION

The Body Mounted Horizon Sensor (BHS) is one of the attitude determination sensors used on the AE-5 spacecraft. The BHS is used to locate the horizon of the Earth by detecting infrared radiation from the effective Earth surface, i.e., the Earth surface including carbon dioxide (CO_2) surrounding the Earth.

Infrared detectors are less susceptible to Sunlight reflected from the spacecraft, are not affected by the presence of uncleared Earth boundary (called terminator) in the visible light spectral region, and can be used at night. There are three basic components in the BHS unit: an optical system, a radiance detector and signal processing electronics. The optical system consists of a filter to limit the observed spectral band and a lens to focus the target image on the radiance detector. The radiance detector consists of a bolometer which is a sensitive resistance thermometer used to detect infrared radiation. The signal processing electronics stores the maximum magnitude of the detected radiation in one spin period of the spacecraft, then generates an Earth-in pulse when the magnitude of the detected radiation in the next spin period exceeds 50 percent of the maximum radiation saved during the previous spin period. Similarly, an Earth-out pulse will also be generated by the signal processing electronics when the magnitude of the detected radiation falls below 40 percent of the maximum radiation.

The BHU has a square field of view (FOV) which is 2.5° ± 10% on each side. The bolometers are sensitive in the 14- to 16-micron bandpass. As the spacecraft rotates, Earth-in and Earth-out pulses are generated by the BHS unit as its field of view intercepts the Earth. The Earth-in and Earth-out pulses are included in the

spacecraft telemetry for ground processing in order to determine the earth width (the time between Earth-in and Earth-out pulses). The spacecraft spin period may be determined from successive Earth-in or Earth-out pulses (or by the other sensors such as the sun sensor). The earth width is used, along with the spacecraft spin period and orbit ephemeris, to determine the spacecraft attitude.

2.0 PURPOSE

The purpose of this test was to evaluate the BHS performance at the DE-A mission mode spin rate (9.9 rpm nominal). The BHS to be used on the DE-A mission is essentially identical to the AE BHS, which operates at a nominal spin rate of 4 rpm.

3.0 METHODOLOGY

The test involved spinning the AE-5 spacecraft up to 10 rpm. The 10 rpm spin rate was achieved by transferring all momentum from the spacecraft momentum wheel into the body. The spin up to 10 rpm (from the nominal 4 rpm) was accomplished within one orbit, followed by the collection of data. The 10 rpm mode of operation was maintained for one orbit.

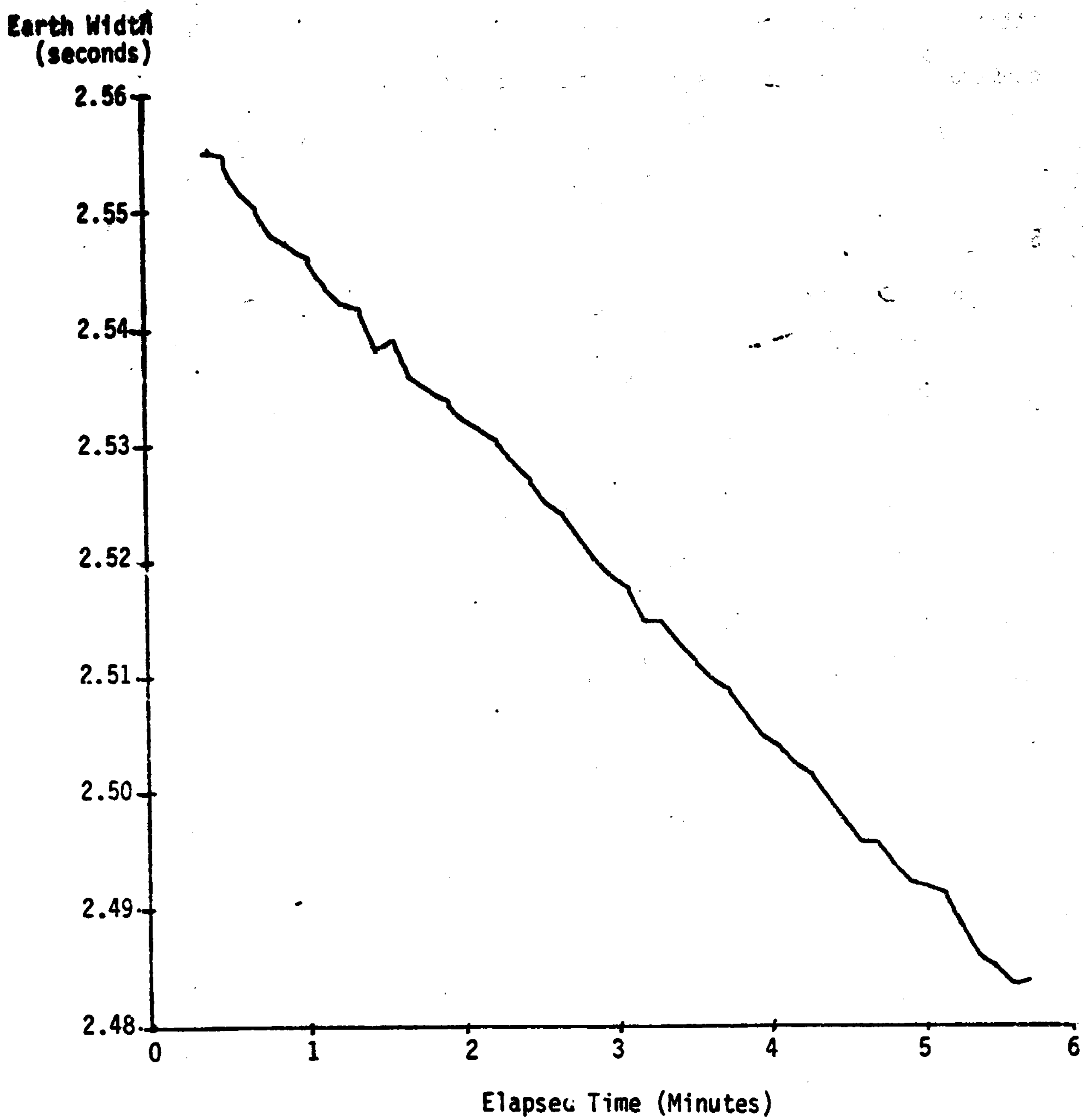
4.0 TEST RESULTS

Figures II-1 and 2 show computer generated plots of the Earth width (ordinate) versus time as the spacecraft was maintained at a constant spin rate of 10 rpm. The slope of the plots is due to change in the spacecraft attitude due to the spacecraft orbit. The deviations from a smooth curve are due to telemetry noise and are not significant. The plots show nominal performance of the BHS, similar to observed BHS

performance with the spacecraft at the 4 rpm spin rate. It should be noted that only a relatively small sample of valid data was obtained during the test because of telemetry problems; however a satisfactory attitude determination was performed using the limited data. Time constraints and normal mission operations did not permit a repeat of this test.

5.0 CONCLUSIONS

The fact that the BHS data at 10 rpm was essentially identical to that obtained at 4 rpm constitutes validation of the BHS performance at 10 rpm.



Start Time: 1130:50(Z); 21 NOV 1980
Spin Rate: 10 rpm

Figure II-1 BHS Earth Width Plot (Part 1)

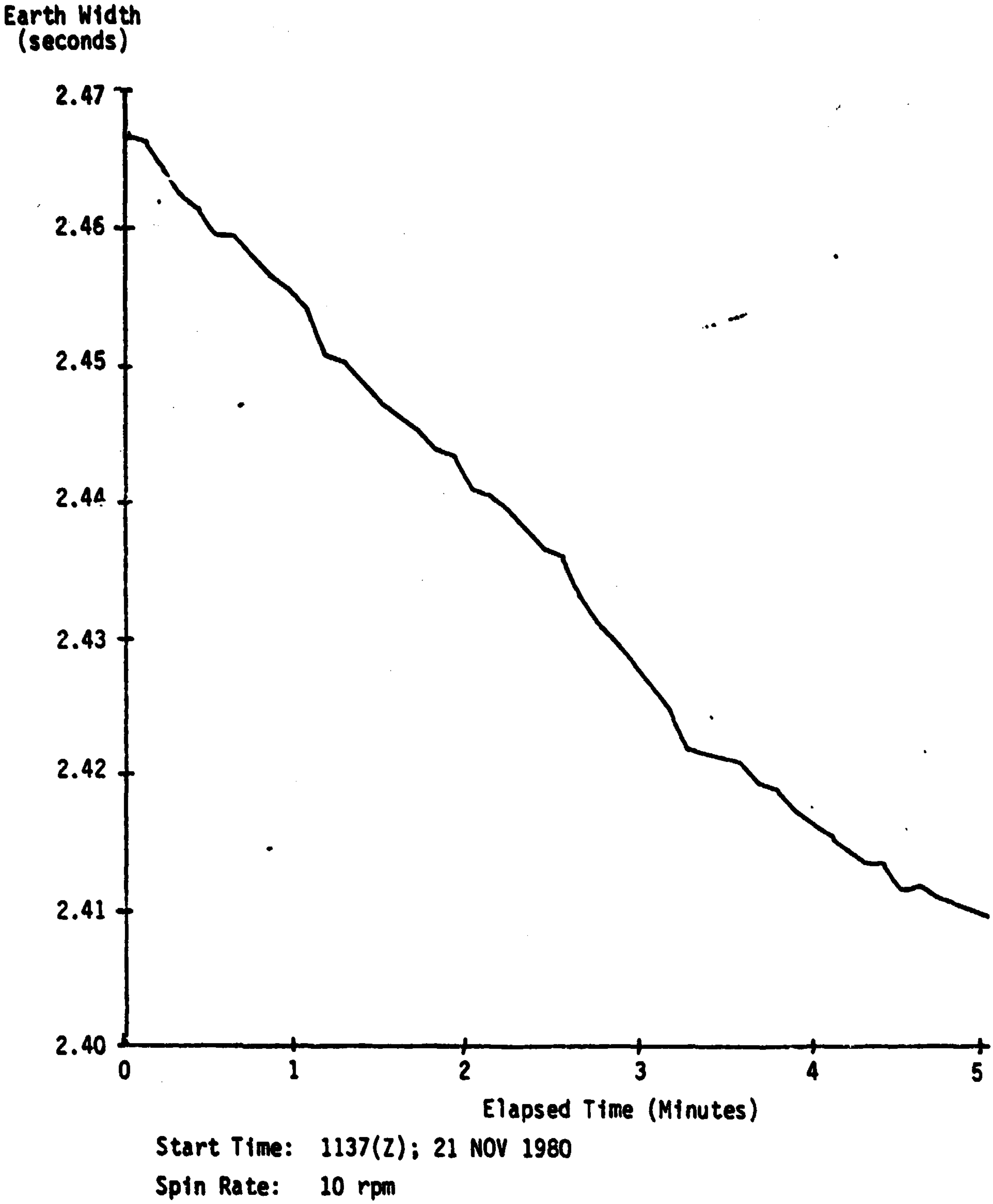


Figure II-2BHS Earth Width Plot (Part 2)

SECTION III

AE-5 END OF MISSION TDRS TRACKING SIMULATION TEST

J. SCHAEFER
F. KISSEL

TABLE OF CONTENTS

SUMMARY

The TDRS tracking simulation test performed in November of 1980 by the AE-5 spacecraft provided data as to the viability of using the TDRSS as a data return link for low earth orbiting spacecraft. The simulation proved that the current ACS used on AE-5 is sufficiently accurate to be used as a basic design for other similar spacecraft intending to use the TDRSS in a like manner. Additionally, the analysis and results of the simulation indicate that such ACS tracking would be a relatively easy chore.

1.0 INTRODUCTION

The AE-5 (Atmospheric Explorer) TDRS Tracking Simulation was proposed because one of the AE successors, the DE (Dynamic Explorer) series, was originally to use the TDRSS S-Band Single Access (SA) link as a data path. However, the revised plan for the DE satellite mission series operations does not include use of the TDRSS. Thus, the TDRS Tracking simulation has no design or operation impacts on the DE satellite series. However, the tracking simulation may be of interest for some future spacecraft design. Also, the tracking simulation provides for an exercise of the AE-5 Attitude Control System (ACS).

This test is part of a series of End-of-Mission tests for the AE-5 spacecraft. The spacecraft was programmed to track the sun (simulating TDRS) with the BUV (Backscatter Ultraviolet) instrument. The spacecraft attitude was recorded and compared with commanded attitude that followed sun ephemeris. The tracking errors thus derived indicate the viability of a future spacecraft using the S-Band SA data link of the TDRS system.

1.1 BACKGROUND

1.1.1 Description of Mission

The results of upper atmosphere missions by the Atmospheric Explorer (AE) satellites (AE-1 through AE-4) have emphasized the continuing need for satellite measurements at the lower altitudes (between 120 and 300 kilometers). The knowledge of the physical properties of this lower thermosphere is highly significant because changes in this part of the atmosphere affect the upper region aeronomy due to vertical transport. The AE-5 satellite was designed to

study this region. The satellite carries experiments which measure neutral and ionic particle temperatures, densities, total atmospheric density or pressure, solar energy spectra at extreme ultraviolet wavelengths, airflow emissions in the ultraviolet, electron temperatures and concentrations, and ionic currents.

The AE-5 mission provided measurements at a complete range of perigee latitudes. By changing the orbit of AE-5 (circularizing), a complete set of diurnal data could be acquired in one orbit period. The unusual capability to control the orbit was made possible by an Orbit Adjust Propulsion System.

1.1.2 Description of Spacecraft

The geometric structure of the AE-5 spacecraft is a 16-sided prism approximately 1.35 m in outside diameter and 1.15 m in height. The general configuration of the spacecraft is shown in Figure III-1. The internal configuration consists of two baseplates separated by a central column and connected by six sheer plates. Experiments and spacecraft equipment are mounted to one side of each baseplate. The BUV (Backscatter Ultraviolet) experiment aperature is open along the +Y axis. Active thermal louvers, located on the bottom of the spacecraft hat, act to remove both solar and aerodynamically generated heat. To keep the thermal louvers viewing cold space, a sun angle of slightly less than 90° is always used. The sun angle is measured from the -Z axis (top hat) to the sunline. Figure III-2 presents the method of reference for measuring sun-angle.

The spacecraft has solar cells mounted on the sides of the outer shells to provide electrical power for the spacecraft and the experiments. Spacecraft batteries allow for daily eclipse operations.

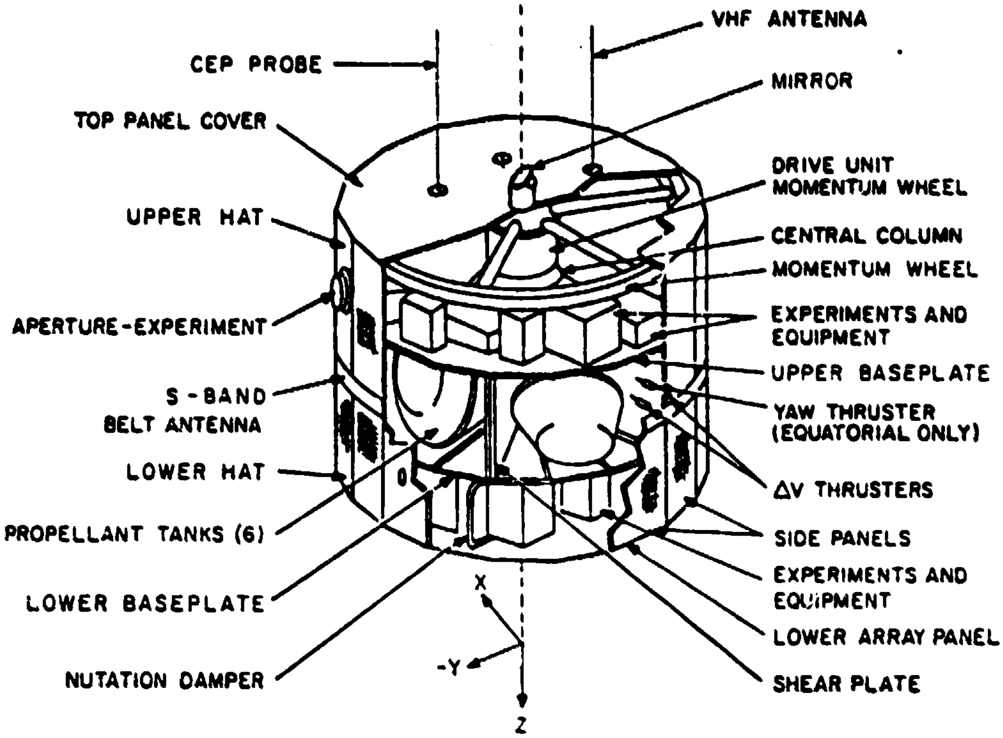


Figure III-1

AE-5 Spacecraft Configuration

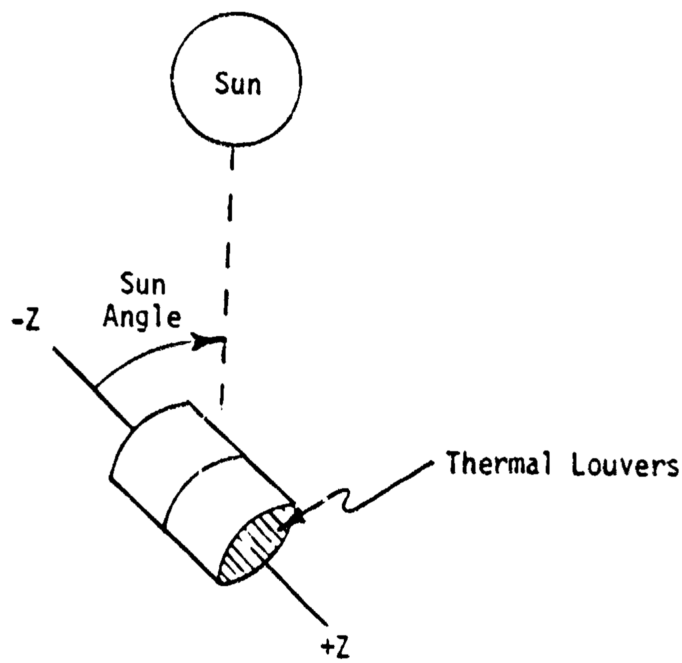


Figure III-2

Sun Angle Measurement Configuration

Experiment sensors view the external environment through aperatures provided in the solar array.

The spacecraft three-axis attitude control system utilizes the momentum wheel to provide roll-yaw stiffening and pitch orientation. Magnetic torque coils are used to maintain momentum axis orientation in inertial space. The spacecraft spin axis is oriented nominally perpendicular to the orbit plane during orbital operations and normal to the relative airstream during low-perigee operations. For the spacecraft instruments, the spacecraft provides a spinning platform in the orbital plane and a despun platform controlled to the local vertical. In the controlled spin mode, the spacecraft spin rate may vary between 0.5 and 8 rpm, with momentum wheel spin rates as low as 40 RPM. In the despin mode the momentum wheel spins at 360 RPM to produce a spacecraft spin rate of 1 revolution per orbit. The range of spin rates are obtained by direct momentum transfer between the wheel and the body.

Attitude sensors for determining the spacecraft attitude consist of infrared horizon scanners and solar-aspect sensors. The horizon scanners measure Y-axis deviation from the local vertical in the despin mode and the spin rate in the spin mode. The horizon sensors are closely coupled to momentum wheel operations. Four two-axis solar aspect sensors determine the sun angle with respect to the spin axis and the spacecraft spin rate.

The Orbit Adjust Propulsion System (OAPS) provides the unusual ability to alter the AE-5 orbit. The OAPS consists of hydrazine thrusters that can be fired while the spacecraft is in either the spinning or the despun mode. The OAPS allows the spacecraft to dive into the region of the atmosphere which normally can only be studied

using sounding rockets and then to recover the spacecraft by controlling the orbit.

1.1.3 Description of Backscatter Ultraviolet (BUV) Instrument

The BUV instrument essentially measures the ultraviolet radiation form the sun and the backscattered ultraviolet radiation from the Earth's atmosphere to determine the ozone profile distribution for the production of total ozone maps.

The BUV instrument consists of the sensor or optics module and the electronics module. The sensor module houses the optical components of the subsystem, the high-voltage power supplies and the first stages of signal processing. The electronics module houses the bulk of the signal processing electronics and circuitry required to support the subsystem.

The optics module consists of a double (tandem) Ebert-Fastic spectrometer in conjunction with a narrow band interference filter photometer. The interferences filter photometer records a 50 A band centered at 3435 A. In the TDRS simulation, the sun was viewed through a transmission diffuser plate mounted in the optical horn of the photometer. Figure III-3 shows the optical layout of the BUV instrument. A slit aperature is placed in the interference filter photometer so that it will have the same field of view as the spectrometer (12° x 12°). Both monochomator and photometer slits are aligned along the spacecraft +Y-axis.

2.0 OBJECTIVE OF TEST

The objective of performing the AE-5 TDRSS tracking simulation is to assess the dynamic performance of the spacecraft Attitude

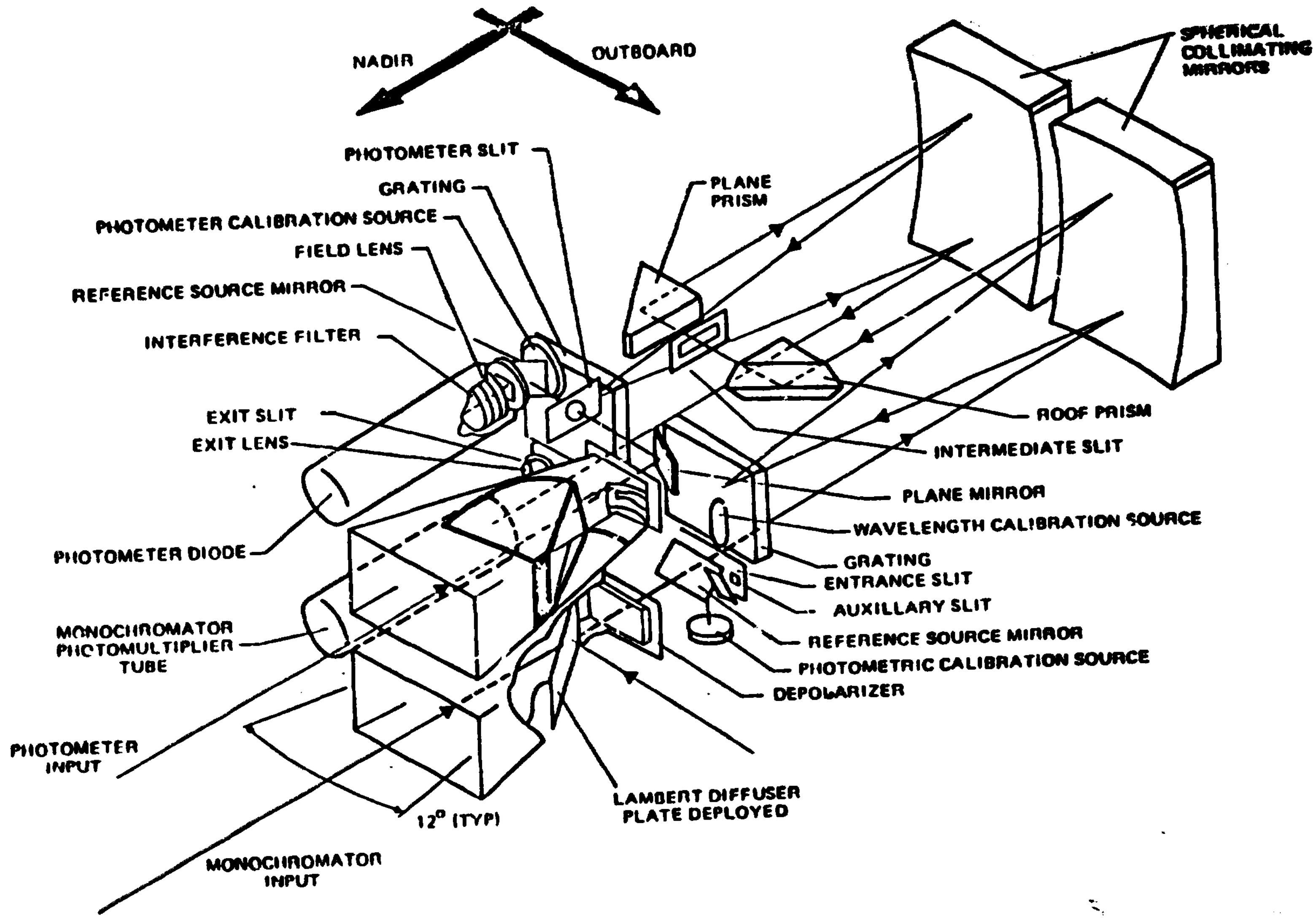


Figure III-3 Optical Diagram of the BUV Photometer and Monochromator

Control System (ACS). The data acquired as a result of this test would achieve three specific objectives:

1. To assure that the ACS can operate in a dynamic situation that allows it to track a near earth synchronous body (in this case the sun simulating TDRS).

2. To allow theoretical predictions of the ACS to be compared with actual in-orbit evaluation.

3. To provide potentially useful test data to be used in future spacecraft design.

3.0 METHODOLOGY

The test procedure for the TDRS tracking simulation involved programming the spacecraft ACS to follow the sun ephemeris. The instrument used to follow the sun was the BUV which is located on the +Y axis of the spacecraft. The orbit of AE-5 during the TDRS simulation was roughly circular at about a 20° inclination. The sun angle of the spacecraft was 88.2°.

Basically, the sun ephemeris was calculated for orbit number 28199 on November 11, 1980. A calculation was made to translate sun ephemeris to AE-5 spacecraft coordinates. A projected time versus +Y axis pitch angle was generated as a result of the coordinate transfer calculations. The start time of the simulation represents the sunrise and the stop time represents the sunset of the spacecraft orbit. Table III-1 presents the BUV worksheet thus generated.

The spacecraft essentially was put into a modified despin mode where the momentum wheel ran at 360 RPM with periodic wheel slowdowns in order to control +Y axis pitch.

Spacecraft telemetry was stripcharted and attitude information was recorded. The stripcharted information provided a rough verification that the procedure was working while the attitude information would provide for definitive attitude determination.

TABLE III-1

BUV WORKSHEET

BUV Maneuver of November 28, 1980

Start Time 801128 . 1405 EPOCH 801122 000000

Stop Time 801128 . 1503 Ascending Node 801128 133800

Time	Pitch Angle	Time	Pitch Angle
1405	116	1434	2
1406	112	1435	358
1407	108	1436	355
1408	104	1437	351
1409	100	1438	347
1410	96	1439	343
1411	92	1440	339
1412	88	1441	335
1413	84	1442	331
1414	81	1443	327
1415	77	1444	323
1416	73	1445	319
1417	69	1446	316
1418	65	1447	312
1419	61	1448	308
1420	57	1449	304
1421	53	1450	300
1422	49	1451	296
1423	45	1452	292
1424	41	1453	288
1425	38	1454	284
1426	34	1455	280
1427	30	1456	276
1428	26	1457	273
1429	22	1458	269
1430	18	1459	265
1431	14	1500	261
1432	10	1501	257
1433	6	1502	253
		1503	249

4.0 ANALYSIS AND RESULTS

4.1 STRIPCHART DATA ANALYSIS

The stripchart data of the simulation provided some indication that the programmed pitch control was working. A typical sample of two channels of the stripchart data are shown in Figure III-4. The stripcharts in Figure III-4 are not quantitatively calibrated. However, basic relationships can be recognized to show the operation of the attitude control system. Nominally, the momentum wheel spins at a 360 RPM rate in the despin mode. Since tracking pitch changes are required in the TDRS simulation, the wheel must periodically slow down to pitch the outside of the spacecraft. The periodicity of the motor current in Figure III-4 verifies the proper ACS operation. Since the spacecraft rotation was changing, the time period between horizon sensors was also changing. The wheel horizon sensor period rises shortly after the attitude control electronics lowers the motor current. This rise in period represents a transfer of momentum from the wheel to the spacecraft body resulting in a spacecraft spin up to change +Y axis pointing. Shortly after the wheel motor current rises, the wheel horizon sensor period decreases indicating a higher momentum wheel spin rate and a lower spacecraft body spin rate.

The stripcharts indicate a small operational time lag (<5 seconds) between the change in motor current and a change in spacecraft body spin rate. Although this might indicate a slow system response, the pointing accuracy is quite high as shall be seen in the analysis of definitive attitude data.

Since the BUV instrument has a 12° x 12° field of view, telemetry information regarding the presence of the sun in the field of view cannot provide accurate pointing information. Consequently, +Y axis pointing accuracy must be derived from definitive data.

4.0 ANALYSIS AND RESULTS

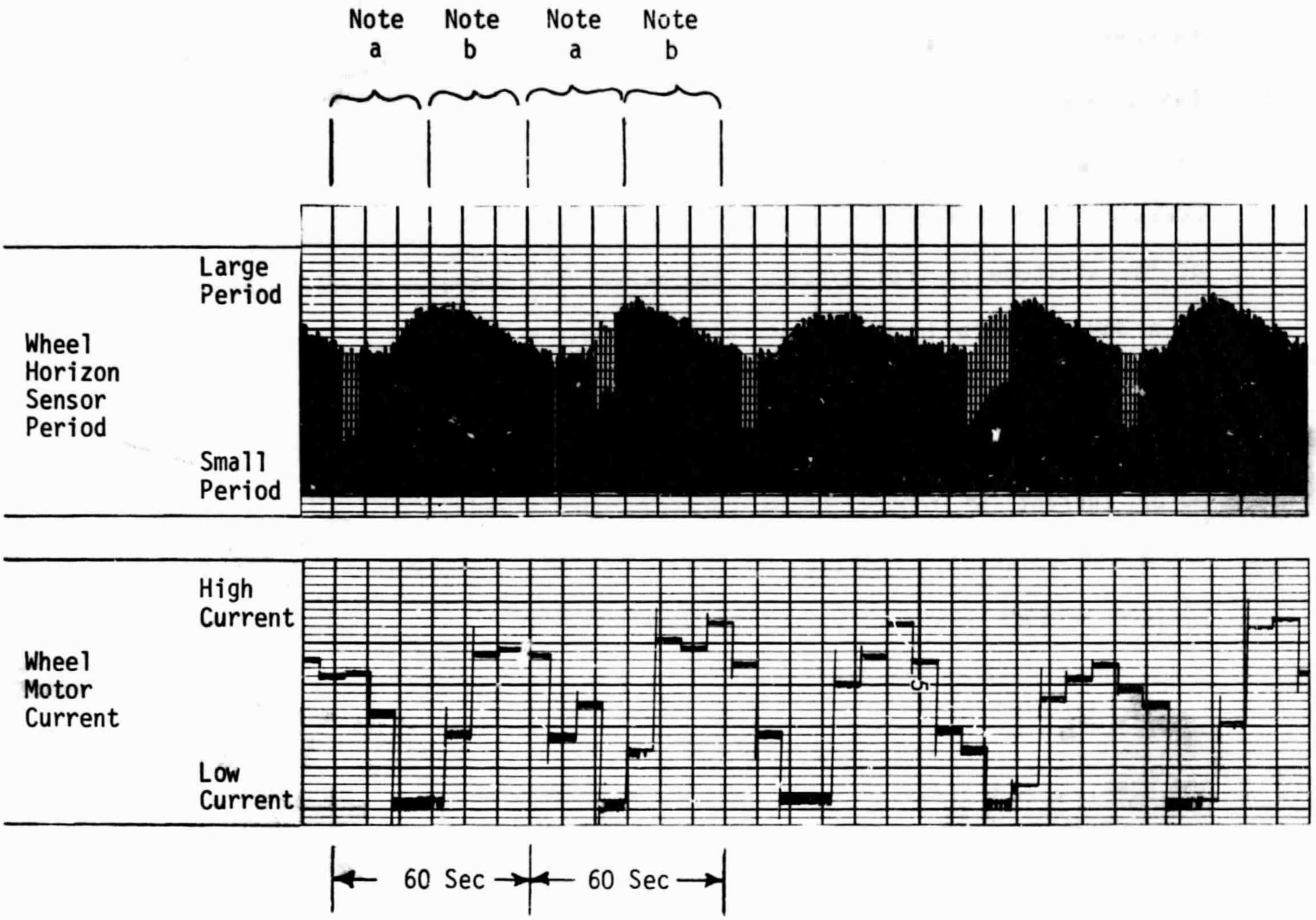
4.1 STRIPCHART DATA ANALYSIS

The stripchart data of the simulation provided some indication that the programmed pitch control was working. A typical sample of two channels of the stripchart data are shown in Figure III-4. The stripcharts in Figure III-4 are not quantitatively calibrated. However, basic relationships can be recognized to show the operation of the attitude control system. Nominally, the momentum wheel spins at a 360 RPM rate in the despin mode. Since tracking pitch changes are required in the TDRS simulation, the wheel must periodically slow down to pitch the outside of the spacecraft. The periodicity of the motor current in Figure III-4 verifies the proper ACS operation. Since the spacecraft rotation was changing, the time period between horizon sensors was also changing. The wheel horizon sensor period rises shortly after the attitude control electronics lowers the motor current. This rise in period represents a transfer of momentum from the wheel to the spacecraft body resulting in a spacecraft spin up to change +Y axis pointing. Shortly after the wheel motor current rises, the wheel horizon sensor period decreases indicating a higher momentum wheel spin rate and a lower spacecraft body spin rate.

The stripcharts indicate a small operational time lag (<5 seconds) between the change in motor current and a change in spacecraft body spin rate. Although this might indicate a slow system response, the pointing accuracy is quite high as shall be seen in the analysis of definitive attitude data.

Since the BUV instrument has a 12° x 12° field of view, telemetry information regarding the presence of the sun in the field of view cannot provide accurate pointing information. Consequently, +Y axis pointing accuracy must be derived from definitive data.

ORIGINAL PAGE IS
OF POOR QUALITY



Notes:

a) Spacecraft Body Spin Up
Momentum Wheel Spin Down

b) Spacecraft Body Spin Down
Momentum Wheel Spin Up

Figure III-4

Stripchart Data Sample

4.2 DEFINITIVE DATA ANALYSIS

The definitive attitude data, derived from computer analysis of the spacecraft attitude sensor data, is accurate to within ±0.5 degrees. The definitive data from the AE-5 TDRS tracking simulation provided the spacecraft pitch angle versus time. Additionally, using sun ephemeris information, the angle between the center of view of the BUV instrument (+Y axis) and the sun was determined for each spacecraft pitch angle. Figure III-5 depicts the measurement of the pitch angle. Here, pitch is described as the angle between the +Y axis and the local horizontal.

A BUV instrument (+Y axis) to sun angle was provided in the definitive data because the sun angle of the spacecraft was not exactly 90°. That is the +Y axis was always pointing off the sun by 1.8° due to the 88.2° sun angle. Consequently, for this simulation, the spacecraft pitch could be controlled, but the 1.8° yaw off the sun line could not. However, the BUV to sun angle might be used as an indicator of the pointing accuracy.

In reviewing the definitive data, it was found that the spacecraft measured pitch angle was extremely close to the programmed pitch angle at the programmed times. The pitch angle was programmed on one minute intervals (see Table III-1). Figure III-6 presents a typical 4 minute sample of the programmed versus measured pitch. On the one minute interval marks, the measured pitch is extremely close to the programmed pitch. The periodicity of the measured pitch curve is a function of the response of the ACS system.

The ACS system of AE-5 was built so that with a momentum wheel speed of 360 RPM, one revolution per orbit could be attained. If the wheel slows down, the spacecraft spins up. So, low wheel speeds

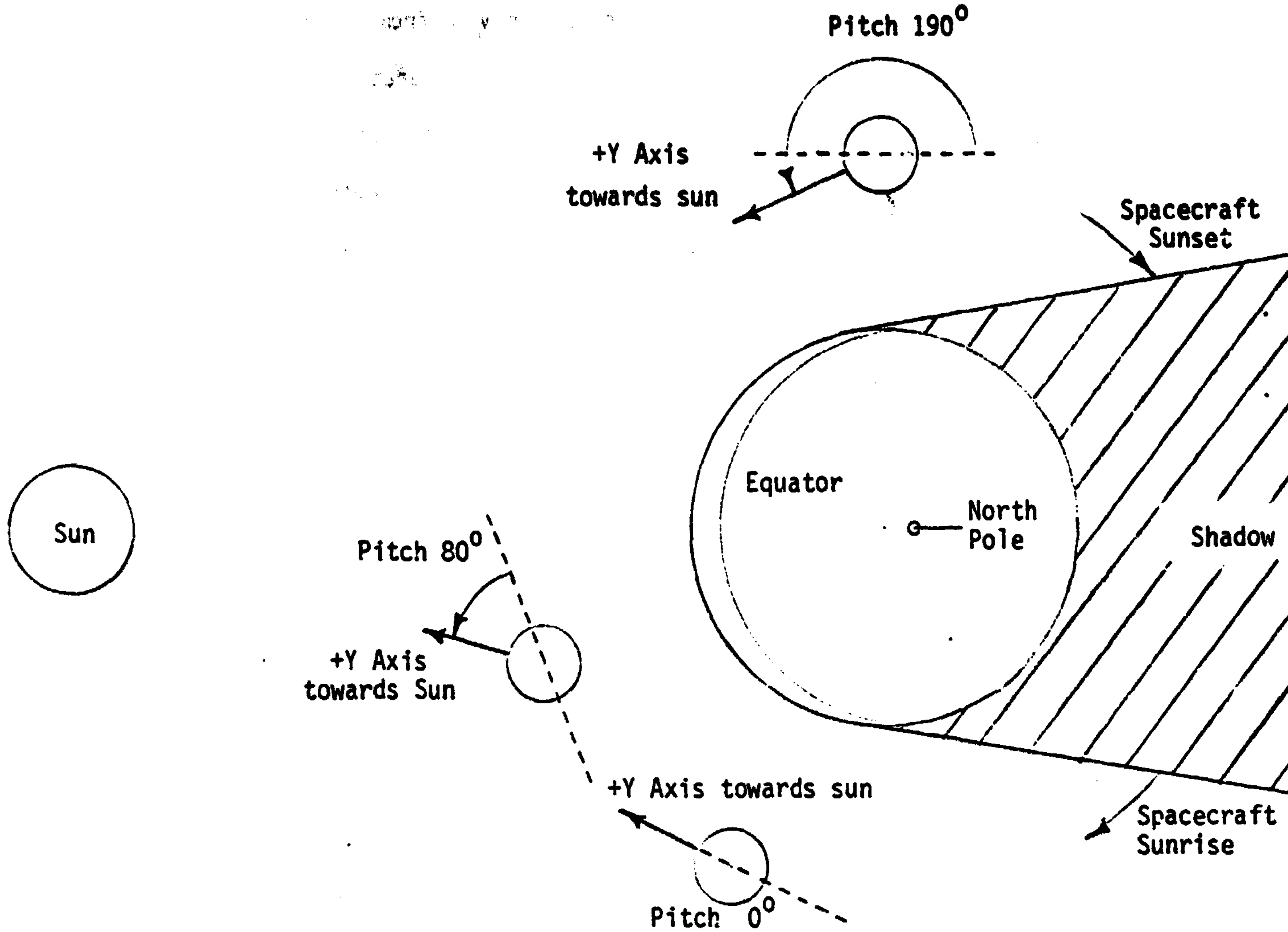


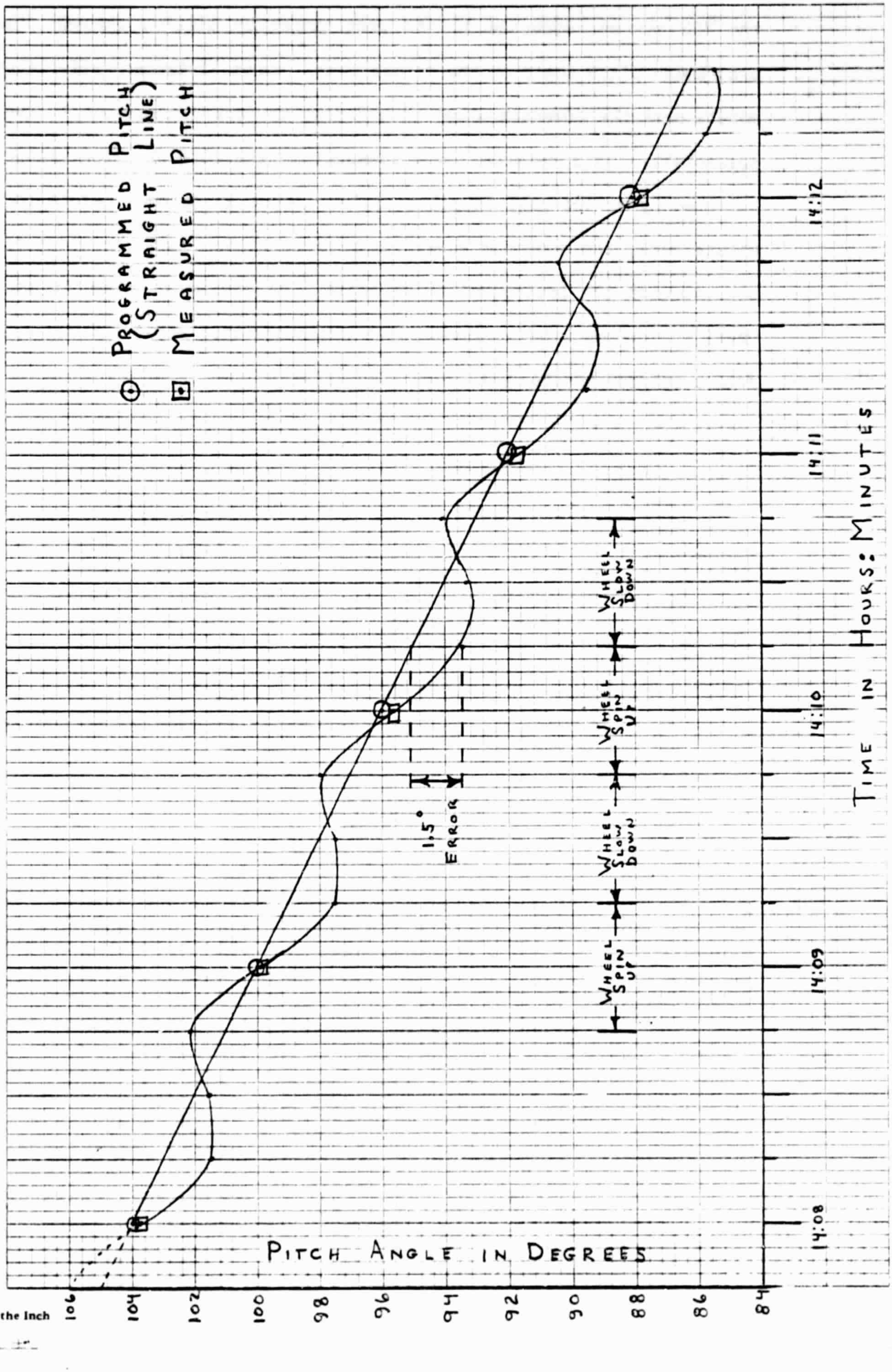
Figure III-5

Configuration of Pitch Angle

Notes:

- o Dotted line is local horizontal
- o Spacecraft +Z axis is out of paper
- o Orbit plane is in plane of paper

Figure III-6
Programmed & Measured Pitch vs Time



correspond to higher spacecraft spin rates. Figure III-6 shows that the ACS system responded to its programming by slewing through the programmed pitch angle on the minute mark. About 15 seconds after the minute mark the momentum wheel slowed down to impart more spin to the spacecraft. This resulted in a slowdown in the rate of pitch change followed by an increase in pitch angle. About 15 seconds before the minute mark, the momentum wheel returned to normal speed in order to slew through the programmed pitch angle. At its worst point in the wheel's slowdown, the measured pitch angle deviated about 1.5 degrees from a between minute mark calculated value.

4.3 TDRSS REQUIREMENTS ANALYSIS

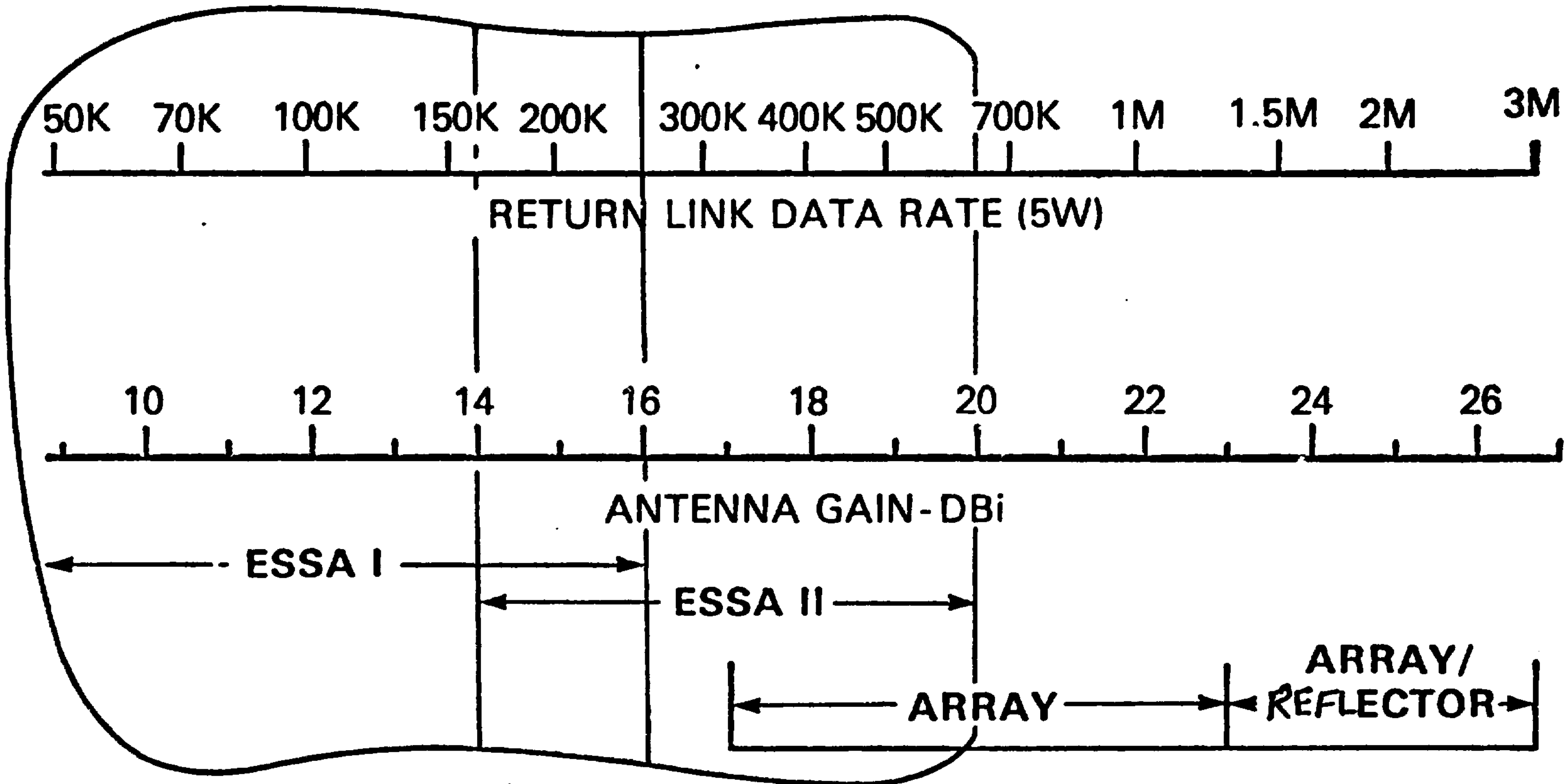
One of the purposes of the TDRS simulation with AE-5 was to determine the viability of the data link between a low orbiting satellite and the TDRS. The Dynamic Explorer (DE) project was to use the TDRS but the project has since changed its requirements. However, an analysis of the TDRS requirements for DE is given here.

In order to assess the TDRSS S-Band Single Access (SA) Return Service requirements on a DE satellite, some assumptions must be made. The assumptions made concern data rates, antenna efficiencies, and TDRS capabilities. The first two DE satellites propose data rates of about 131 Kbps. A DE TDRS tracking antenna efficienty of 50% will be assumed. Figure III-7 presents a TDRS S-Band SA return link antenna guideline. This quideline is not official, however, it is believed to be accurate enough for a first order analysis. Using Figure III-7, it can be seen that a 131 Kbps return data link rate would require a spacecraft (DE) antenna gain of about 13 or 14 dBi. This is well

Figure III-7

S-BAND SINGLE ACCESS USER RETURN LINK ANTENNA GUIDELINES

STANDARD GSTDN/TDRSS TRANSPONDER



RANGE = 42,510 KM; Lp = 0.1dB; 3FT RF CABLE;
M = 3dB; γ = 2.5dB; TDRSS USERS' GUIDE

within a practical range. The beamwidth required for a 50% efficient antenna of 13 dBi can be found as follows:

$$BW = \frac{41{,}253 \times 0.5}{G}$$

where 41,253 is the number of square degrees subtended by all space and where G is a power ratio [$G = 10^{(dBi/10)}$]. Solving the equation:

$$BW = \frac{20626.5}{19.9}$$

$$= 32.15 \text{ degrees}$$

This is the beamwidth in degrees that the DE satellite would have to use for the TDRS SA return link.

4.4 RESULTS

The analysis of the tracking simulation indicate that the attitude control system can indeed operate in a dynamic situation that allows it to track a near earth synchronous body. The pitch plane tracking error was well within 2 degrees. This proved that a high degree of accuracy exists between predicted or programmed pitch angles and the corresponding angles measured onboard the spacecraft.

Additionally the analysis indicates that a DE satellite with a 13 dBi antenna gain and a 131 kbps bit rate requires a 32 degree antenna beamwidth to use the TDRS S-Band single access return data link. If the DE satellite had an ACS similar to that of AE-5, the tracking of and data transmission to the TDRS would be a relatively easy chore assuming a pointing accuracy of less than 2 degrees.

5.0 DISCUSSION/CONCLUSION

5.1 DISCUSSION

Although it was relatively easy for the AE-5 BUV instrument to track the pseudo TDRS, the application of an ACS in this manner is complicated slightly by the type of spacecraft and antenna used. In the case of a spin stabilized spacecraft, the onboard ACS must be able to point either a despun antenna or an electronically despun antenna at the TDRS. In the case of a three-axis stabilized spacecraft, the onboard ACS must be able to point a fixed or only partially steerable antenna at the TDRS. However in either case, the antenna pointing slew rates, (rate of change in antenna pointing), are comparable. It is also well to note that for low earth orbiting spacecraft, the antenna pointing slew rates necessary for pointing at a geostationary object are less than those slew rates necessary for pointing the same spacecraft antenna at a ground station. Consequently, the spacecraft antenna moves more slowly in tracking a geostationary object than in tracking a ground station. The effect is that the low earth orbiting spacecraft can track a geosynchonrous spacecraft with greater accuracy than it can track a ground station. The major assumption is, of course, that the positions of two spacecraft are well known.

5.2 CONCLUSION

The TDRS tracking simulation test performed by the AE-5 spacecraft has provided information for all three of its objectives.

1. The AE-5 ACS can indeed operate in a dynamic situation that would allow it to easily track the TDRS.

2. The theorectical prediction of the ACS performance were compared with actual in-orbit conditions. The ACS can track within a 2 degree accuracy.

3. The potentially useful information for future spacecraft design lies in the conclusion that the AE-5 ACS is fundamentally a good design for the tracking of the TDRS.

REFERENCES

a) "NASA Support Plan for the Atmosphere Explorer D&E"
R.V. Tetrick and David J. Pine, March 3, 1975.

b) "System Description for the Atmosphere Explorer-5 Backscatter Ultraviolet Experiment (BUV)"
R. Dasgupta and Dr. P.V. Rigterink, Computer Sciences Corporation, January 25, 1977

c) "Mission Requirements and Network Support Forecast"
GSFC STDN No. 803, July, 1981

d) "Reference Data for Radio Engineers" Fifth Edition, Chapter 25, ITT, October, 1968